SEARCH FOR GAMMA-RAYS ABOVE 400 GeV FROM GEMINGA

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A B S T R A C T

Observations of Geminga made at the Whipple Observatory using the atmospheric Cherenkov technique during the moonless periods of November 1983 - February 1984 and November 1984 - February 1985 have been examined for evidence for the emission of gamma rays with energy in excess of ~ 400 GeV. The data were searched for evidence of either a steady flux or a flux pulsed with a period near 60 seconds. In neither case was any significant effect observed, enabling us to establish 3 sigma upper limits of 5.5×10^{-11} photons cm^{-2} s^{-1} and 2.0×10^{-11} photons cm^{-2} s^{-1} for the steady and pulsed emission respectively. The limit to the pulsed flux is approximately a factor of six below that predicted by Zyskin and Mukanov (1983) at this energy.

1. Introduction. The high energy gamma-ray source Geminga (2CG 195+4) was discovered by the SAS-II experiment in 1975 (Kniffen et al, 1975; Thompson et al, 1977) and was independently detected and studied in greater detail by the COS-B experiment (Hermsen 1983). With an integral flux of $\sim 5.10^{-6}$ photons cm^{-2} s^{-1} at 100 MeV it remains, ten years after its discovery, the brightest unidentified object (and second brightest overall) in the sky at these energies. Its intensity, combined with its location in the direction of the galactic anticenter, have made it a prime candidate for identification with objects detected at other wavelengths. At the present time the available evidence points to, but is incapable of deciding between either a nearby (~100pc) soft spectrum x-ray source, possibly a collapsed star, (Bignami et al, 1983) or an extragalactic, flat-spectrum radio source (Spelstra and Hermsen, 1984; Moffat et al, 1983).

Since the early suggestion of a possible, ~59-second, periodicity in the 100 MeV gamma-ray flux (Thompson et al, 1977) further information on the nature and possible counterpart of Geminga has been sought from studies of the time variability of its emission. Again the present experimental situation appears confused with evidence being presented both in favor of (Zyskin and Mukanov 1983; Bignami et al, 1984) and against (Buccheri et al, 1984) the existence of such a periodicity.

In this paper we present results of a search for a flux of gamma rays, either continuous or pulsed, with energies in excess of ~400 GeV from the direction of Geminga.

2. Data. The data were taken with the F.L. Whipple Observatory 10-meter reflector (Cawley et al, paper OG 9.5-4, this conference) on clear moonless nights during the periods Nov 1983 - Feb 1984 and Nov 1984 - Feb 1985. Observations were generally made by alternately tracking the source ("ON" SCAN) and a comparison region ("OFF" SCAN) over the same range of zenith and azimuth angles for periods of 28 sidereal minutes. On occasion the source was tracked continuously for periods of ~ 3-6 hours to facilitate the search for pulsed emission. On all occasions the arrival time of each air shower was recorded, with the aid of a clock synchronised to WWVB, to an absolute accuracy of ±0.5 msec, with a resolution of 1μs.

3. Analysis. Before being incorporated in any analysis all scans, for both "ON" and "OFF" regions, were examined for evidence of possible systematic effects e.g. significant deviation from Poisson counting statistics. This resulted in the elimination of 10 "ON-OFF" scan pairs from the original sample of 38 pairs taken under good observing conditions. Three scans, in which Geminga was tracked continuously were also judged suitable for analysis.

3.1 Steady Emission. The raw data from the 28 "ON-OFF" scan pairs comprise a total of 87,983 showers "ON" and 87,419 "OFF" an excess of 564 events (1.4σ) implying a 3 sigma upper limit to the flux above 400 GeV of 3.9×10^{-10} photons cm^{-2} s^{-1}. The raw data were then subjected to a cut designed to preferentially pass gamma-ray initiated showers whilst rejecting nuclear initiated showers with an efficiency of ~90% (Cawley et al paper OG 2.3-1 these proceedings). The total numbers of events in this enhanced sample were 1,352 "ON" and 1,253 "OFF" -- the excess of 99 events is not judged to be significant, differing from zero by 1.9 sigma. Assuming a collection area of 1×10^4 m^2 for these selected events (Cawley et al. OG 9.5-4 these proceedings) the observing time of 766 minutes implies a 3 sigma upper limit of 5.5×10^{-11} photons cm^{-2} s^{-1}. This limit is plotted in figure 1 along with the results of other experiments.

3.2 Periodic Emission. Fifteen hours of data, from four separate nights, in which Geminga was tracked have been examined, independently, for evidence of possible pulsed emission near a period of sixty seconds. The time of arrival of each event passing the cut designed to preferentially select gamma rays was folded at periods in the range 58.75-61.75 seconds and, to facilitate comparison with other experiments, the resultant phase distribution displayed as a twenty bin histogram and tested against uniformity with chisquare. The period was incremented uniformly over the

range scanned in steps of $(58.75)^2/(2x20xT)$ seconds, where T is the duration of the scan in seconds. The maximum reduced chisquare observed in any scan was 2.3 (19 dof) corresponding to a chance occurence probability of 10^{-3}, as there were 300 independent trial periods used in the analysis of this scan the probability reduces to 0.3. No systematic trend in the period associated with the maximum chisquare of individual scans was noted.

From the four nights' observations a 3 sigma upper limit to the pulsed flux of $2.3x10^{-11}$ photons cm^{-2} s^{-1} was established.

4. Conclusions. From a comparison of 13 hours of "ON" and "OFF" source data and 15 hours of tracking data we deduce 3 sigma upper limits of $5x10^{-11}$ photons cm^{-2} s^{-1} and $2.3x10^{-11}$ plates cm^{-2} to the steady and pulsed flux of gamma rays above 400 GeV from Geminga. The latter flux is approximately a factor of six below that predicted by the $E^{-1.3}$ extrapolation of Zyskin and Mukanov(1983) between their observations at 1000 GeV and those of COS-B at 0.1 GeV. Thus Geminga has not been confirmed as a source of VHE gamma rays.

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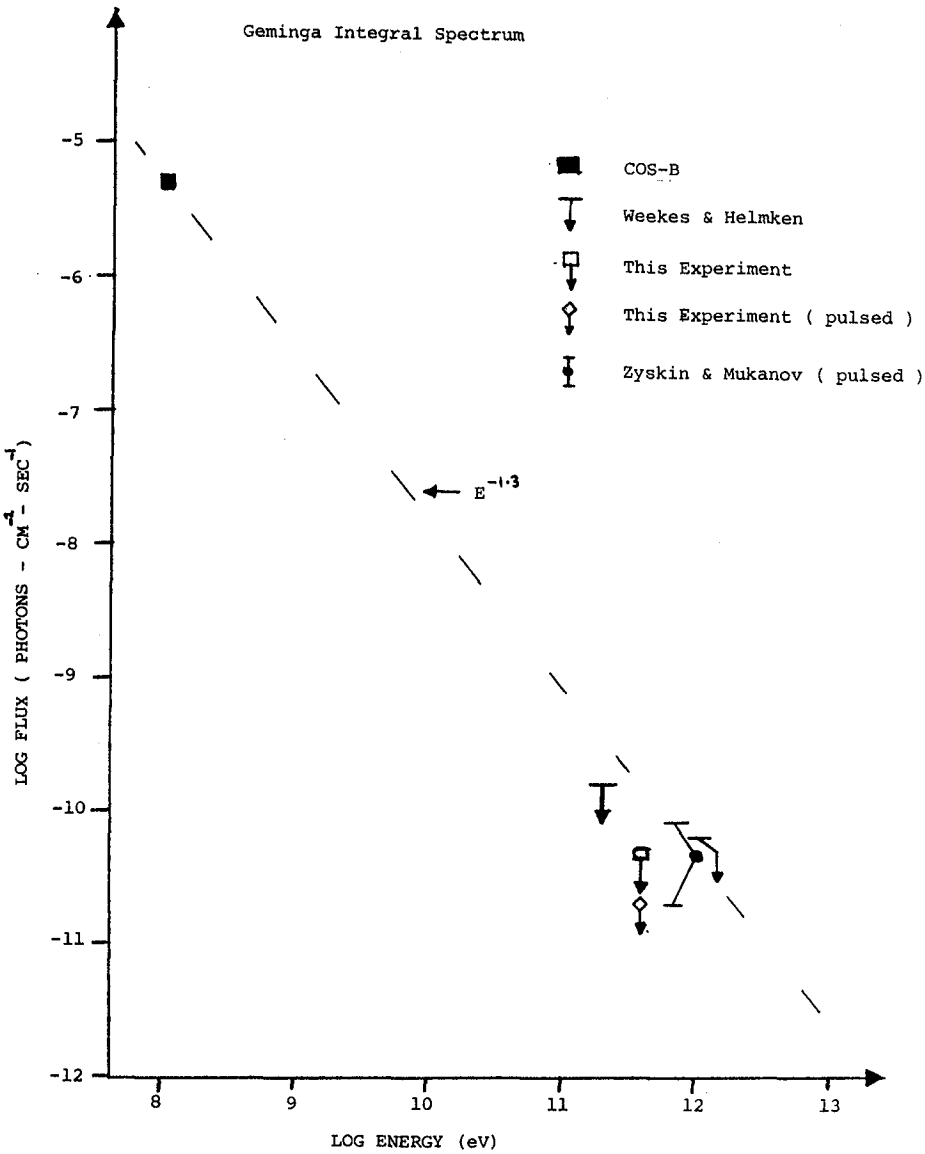

Figure 1. The integral energy spectrum.